Summary of Water Quality Monitoring for Isoxaflutole (Balance herbicide) in Nebraska

Nebraska Department of Agriculture
Bureau of Plant Industry

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The herbicide isoxaflutole (Balance) was registered for use on field corn before the 1999 growing season. Because of concerns about its mobility, potential health effects, and phytotoxicity, isoxaflutole was conditionally registered for three years. After this period, the U.S. Environmental Protection Agency (EPA) will evaluate the results of monitoring studies and modeling to determine continued registration.

Through physical and chemical action, isoxaflutole degrades quickly into two compounds: the primary metabolite, 202248, and the terminal metabolite, 203328 [1]. Most of the herbicidal activity from this product occurs from the primary metabolite. The European Community's Scientific Committee on Plants determined that while there appeared to be no threat of groundwater contamination by the parent compound or 202248, model calculations for the terminal metabolite exceeded its standards of 0.1µg/L (one tenth of one part per billion).[2] It also determined that metabolite 202248 was 10 - 100 times less toxic than isoxaflutole to algae, *Daphnia* species, and fish, while metabolite 203328 was more than 100 fold less toxic to these species. The EPA determined that metabolite 202248 is highly toxic to terrestrial plants and that it may accumulate to concentrations in surface and ground waters, potentially resulting in harm to non-target plants.

Isoxaflutole has been identified as a probable human carcinogen. Because of its sole use on field corn and because of the restrictive measures identified on the label to protect ground water, EPA determined there would be little chance of human consumption and that the risk of cancer from the use of isoxaflutole would be less than the agency's acceptable risk of one in a million.

Labeling for this product prohibits use on sites having porous soils with less than 2% organic matter and a water table less than 25 feet from the ground surface. In addition to the label restrictions and intensive monitoring studies to be conducted by the registrant, EPA required the registrant to analyze samples collected by those states where isoxaflutole is registered.[3] Up to 5,000 samples were to be analyzed for isoxaflutole and two metabolites annually. The sampling kits, shipping and handling, and the cost of the analysis were to be provided by the registrant, Aventis.

In March, 2000, the Nebraska Department of Agriculture (NDA) requested the assistance of local, state, and federal agencies involved in water quality monitoring to obtain samples for the purpose of characterizing isoxaflutole's movement in Nebraska waters. To better target this effort, NDA offered to collect records of isoxaflutole use in those areas where water quality samples would be collected.

Results

Several organizations volunteered to collect samples, many in conjunction with their ongoing monitoring efforts (Table 1). A total of 688 water samples were collected from 149 sites in eastern and southern Nebraska (Fig. 1). Samples were collected from both ground and surface waters, which ranged from runoff to impoundments to streams. The presence of isoxaflutole or its metabolites was detected in 17% of these samples (Table 2). The largest number of detections were found in creeks or rivers, however this type of site represented 82% of the samples collected.

Table 1. Summary of contributors of data

Contributor	Number of sites	Number of samples
NDEQ - ground water section	6	6
NDEQ - surface water section	54	550
Little Blue NRD	19	19
NDA	10	18
Upper Big Blue NRD	57	57
UNL Water Sciences Lab	3	38

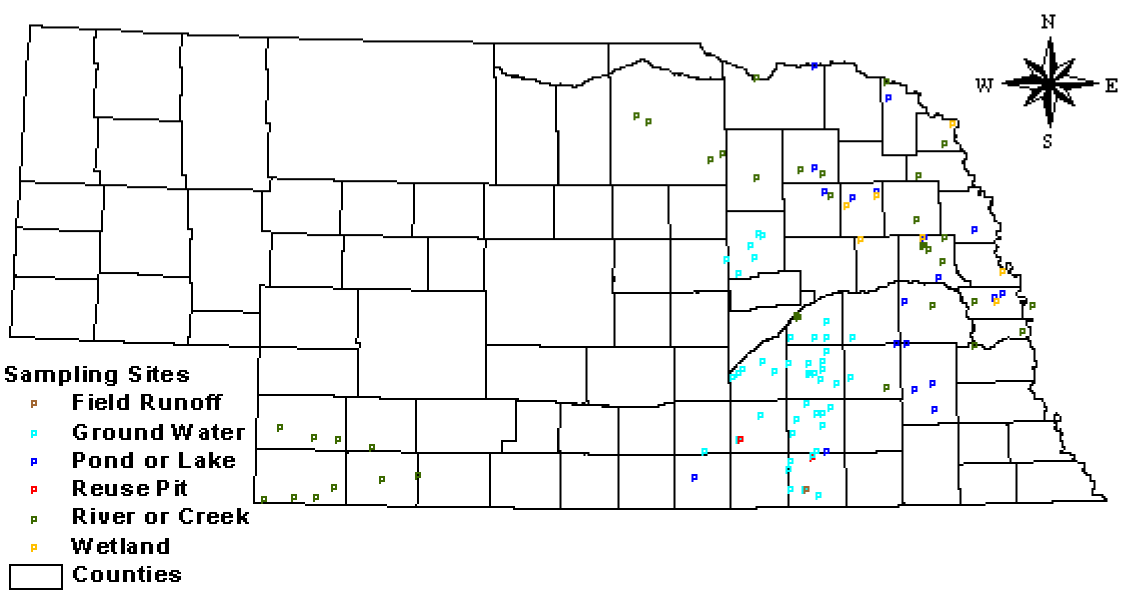

Figure 1. Sites sampled for isoxaflutole.

Table 2. Summary of samples analyzed for Balance herbicide and its metabolites in Nebraska.

Type of Site	Number of sites or sampling points	Number of samples	Number of detections§	Number of samples taken downhill of known applications of Balance¶	Number of detections downhill of known applications of Balance
Ground Water	72	72	1	2	0
Irrigation Reuse Pit	4	4	3	3	3
Ag Runoff	2	2	1	1	1
Pond or Lake	23	33	9	3	2
River or Creek	40	569	104	38	27
Wetland	8	8	1	0	0
Totals	149	688	119	47	35

§ - Includes all samples with detectable levels of Balance herbicide or its metabolites. The level of detection for these samples was 3 parts per trillion (ppt). The level of quantification, however, is 10 ppt.
¶- Not included were samples having incomplete data sheets, or where 'uphill' or 'unknown' was listed as the location of the sample in relation to the application.

It should be noted that the method of analysis has a very low detection level. Concentrations as low as three parts per trillion (ppt) can be detected (limit of detection) and concentrations of 10 ppt or greater can be quantified (limit of quantification) [4].

Because most of the samples were taken as part of regular or ongoing monitoring programs having other objectives, only a small percentage were collected from locations having a pesticide application of isoxaflutole nearby. Of those samples where an isoxaflutole application was known, 75% contained detectable levels of the parent compound or its metabolites.

Table 3 displays the average concentration of isoxaflutole and its metabolites by sampling site. This table represents all 688 samples. The highest concentrations were found in surface water impoundments, and belonged to the metabolites. This is reflective of the short half-life of the parent compound, which is estimated to be 1 to 3 days, and also of the high solubility and persistence of the metabolites (Table 6).

Table 3. Average concentration of Balance herbicide and its metabolites by type of monitoring site, in parts per trillion (ppt). Samples having detectable concentrations greater than 3 ppt but below the level of quantification (10 ppt) were entered as 5 ppt.

Type of Site (number of samples)	Isoxaflutole	202248 metabolite	203328 metabolite
Ground Water (72)	0	0	0.07
Irrigation Reuse Pit (4)	0	108.50	318.25
Ag Runoff (2)	0	17.00	48.5
Pond or Lake (33)	0	27.39	67.84
River or Creek (569)	0.22	5.12	2.87
Wetland (8)	0	1.75	0.63
Overall Average (688)	0.18	6.25	7.64

Table 4 shows the average concentrations of these three compounds from only those samples having detects. Figure 2 corresponds with Table 4, but shows the proportion of detects grouped by analyte. Most of the detections were under 50 ppt, however two samples contained combined concentrations of the metabolites of over 1400 ppt, or 1.4 ppb (Fig. 3). These concentrations were found in a pond and an irrigation reuse pit. Both of these sites were down gradient of a known isoxaflutole application.

Table 4. Average concentration of Balance herbicide and its metabolites for those samples with detectable levels; the number of samples is in parentheses. Samples having detectable concentrations of greater than 3 ppt but below the level of quantification (10 ppt) were entered as 5 ppt. (n = 119)

Type of Site	Isoxaflutole	202248 metabolite	203328 metabolite	Average Primary to Terminal Metabolite Ratio§
Ground Water	-	-	5.0 (1)	-
Irrigation Reuse Pit	-	144.67 (3)	424.33 (3)	0.37 (3)
Ag Runoff	-	34.0 (1)	97.0 (1)	0.35 (1)
Pond or Lake	-	113.0 (8)	249.11 (9)	1.92 (8)
River or Creek	10.58 (12)	34.26 (85)	20.41 (80)	1.84 (69)
Wetland	-	14.0 (1)	5.0 (1)	2.80 (1)
Overall Average	10.58 (12)	43.86 (98)	55.32 (95)	1.79 (82)

§ - Applies only to those samples having detects of both metabolites.

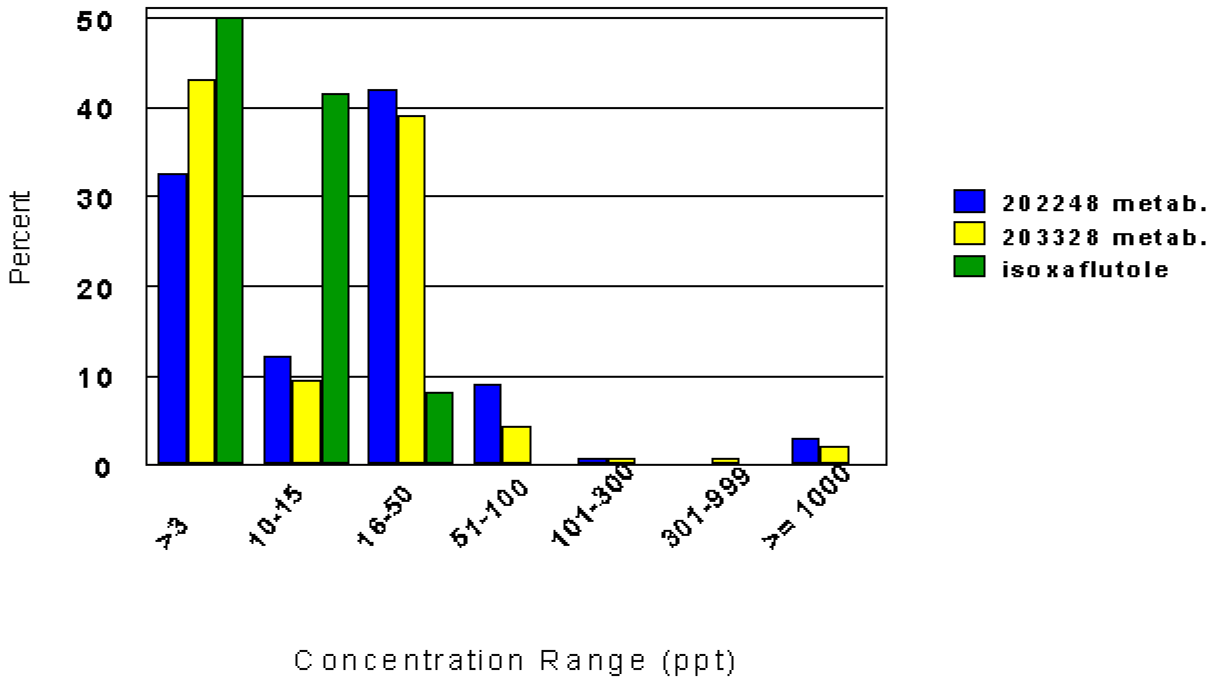

Figure 2. Proportion of detects grouped by analyte. The category ">3" are for those samples that were detectable but less than the quantification limit. n = 119 samples having a detect.

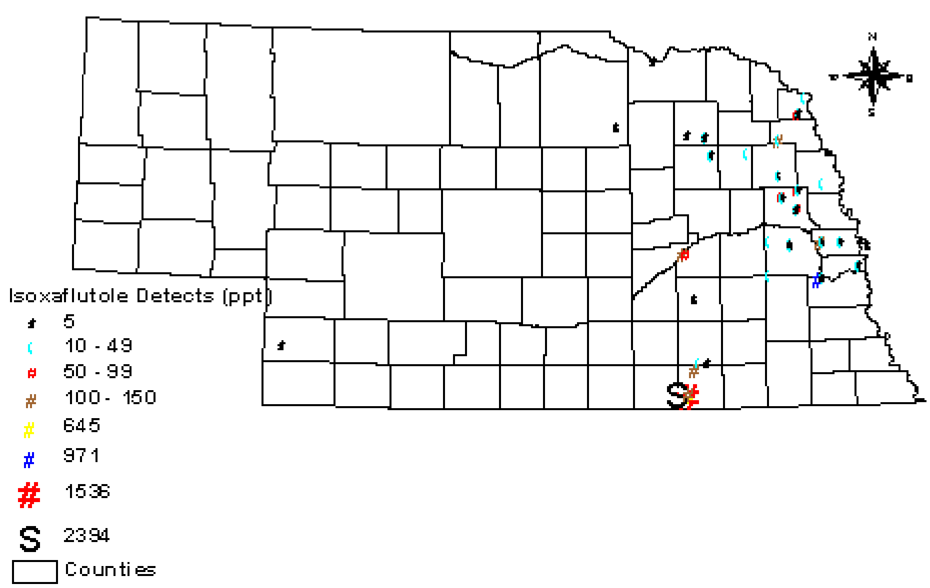

Figure 3. Sites having detects showing relative concentrations of all analytes summed for each location. Detects greater than 3 ppt but less than 10 ppt are labeled as '5'.

Table 5 represents only those data collected from sites where a known isoxaflutole application was made. Figures 4 and 5 display these data by type of site. Again, as would be expected, the higher concentrations were found in impoundments and were for the metabolites.

Table 5. Average concentration of Balance herbicide and its metabolites. Includes only those samples, regardless of concentration, where a known Balance application had been made up-gradient of the sampling site. Samples having detectable concentrations greater than 3 ppt but below the level of quantification (10 ppt) were entered as 5 ppt. (n = 47)

Type of Site (number of samples)	Isoxaflutole	202248 metabolite	203328 metabolite	Average Primary to Terminal Metabolite Ratio§
Ground Water (2)	0	0	0	-
Irrigation Reuse Pit (3)	0	144.67	424.33	0.37 (3)
Ag Runoff (1)	0	34.00	97	0.35 (1)
Pond or Lake (3)	0	277.33	735.67	0.47 (2)
River or Creek (38)	0	31.11	24.08	1.34 (27)
Wetland	-	-	-	-
Overall Average (47)	0	52.81	95	1.17 (33)

§ - Applies only to those samples having detects of both metabolites.

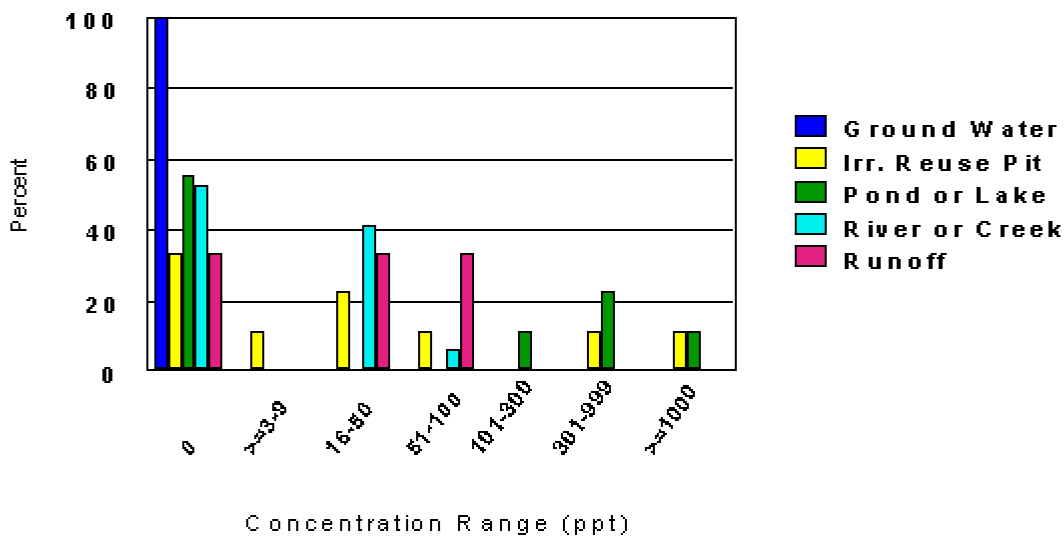

Figure 4. Concentration range of samples with known applications of isoxaflutole, including those without detects, grouped by type of sampling site. All analytes are included; each is counted as a sample for this graph (n = 47 samples from Table 4 multiplied by 3 analytes = 141).

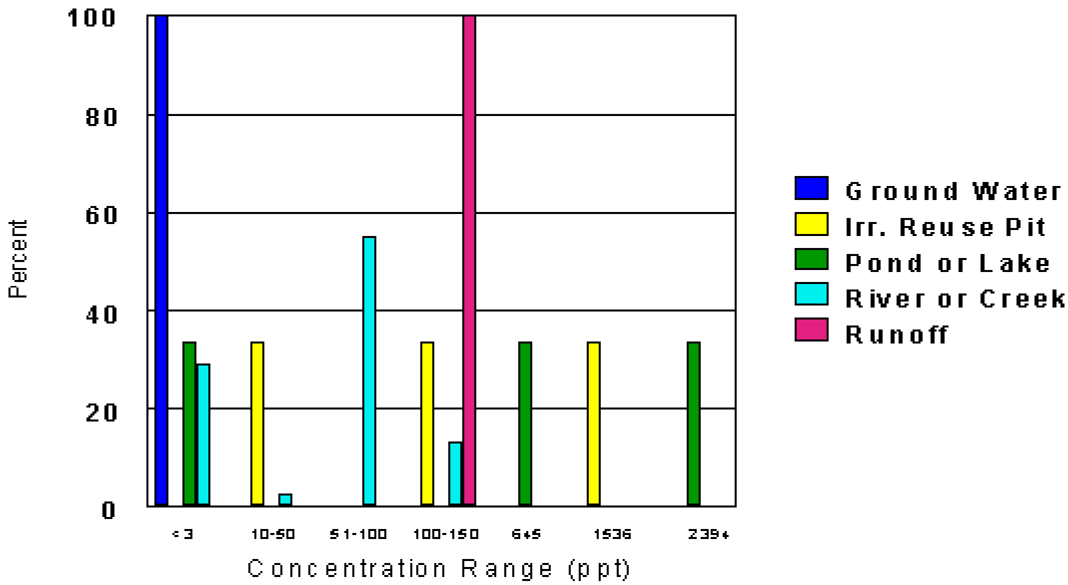

Figure 5. Concentration range of samples with known applications of isoxaflutole, grouped by type of sampling site. Data correspond to those of Table 5 and Figure 4, except that the concentrations shown are the sum of all of the analytes for each sample (n = 47).

Conclusions

Because most of Nebraska's drinking water comes from ground water, human health is a concern when pesticide products are soluble and mobile. Very few ground- water samples were collected for the effort in Nebraska (72). Only two were sampled near a known application; neither contained detectable levels of any of these compounds. However, the depth of these two wells was 143 and 197 feet; depths where contamination would not be expected because of the short amount of time this product has been available for use. Only one of the 72 samples from ground water contained detectable levels, but it was far below the level assigned to drinking water (refer to Table 6). The depth for this well was unknown or not provided.

Although the concentrations found in streams and rivers were relatively low, precipitation and subsequent runoff were fairly low for the year 2000. The concentrations in 1999 may have contrasted with these data had samples been collected that year. Very little drinking water is derived from surface waters in Nebraska, however, the presence of contaminants is still a point of concern. Recent findings indicate that ground water drawn from aluvial aquifers is being affected by contaminants in surface waters. Water drawn from large capacity wells placed horizontally under rivers is essentially replaced by surface water, along with the often higher concentrations of contaminants associated with surface water.[9] In addition, impoundments used as drinking water sources can be affected greatly by contaminated runoff many miles upstream. For example, herbicide concentrations exceeding the drinking water standard in Tuttle Creek Reservoir are caused by runoff coming from the large percentage of agricultural land found in the Big Blue River watershed.[10]

While isoxaflutole is applied at rates 11 to 24 times lower than other common herbicides in Nebraska (Table 6), the concentrations found in the irrigation reuse pits are proportional to concentrations of other herbicides when compared to their respective application rates (Roy Spalding, pers. comm). This would indicate that pesticide movement is more a factor of soil and pesticide characteristics than the rate of application, assuming the environmental and management factors are constant.

Interpretation of these data should be limited to what they were intended to do, that is, to give NDA a point of reference and possibly make recommendations on future registration and/or labeling issues. Most of the sampling sites (107 out of 149) were only sampled once, giving a brief snapshot of what was happening at that point in time. It is hoped that future sampling for this product could not only be targeted to areas with known herbicide applications, but that multiple samples could be taken to account for precipitation and irrigation events. In addition, data from wells pumped from the top of the aquifer, especially in areas having a shallow depth to ground water, would give a better indication of the product's movement to potential drinking water sources.

Table 6. Comparison of application rates, chemical properties, and chronic toxicity of commonly used herbicides [§,5].

Common Name	Maximum Application Rate[¶] (oz dry active ingredient [a.i.]/acre/year)	Estimated Use Rate in Nebraska for Corn (oz a.i./ acre/yr) [6]	Percent of Corn Acres Receiving Application (8.6 million total) [6]	Solubility (mg/L or ppm)	Half-Life (days)	K_{OC}[†] (ml/g)	Human Toxicity (ppb) [‡, 7]
acetochlor	29	25	20	223	14	150	
alachlor	62	33	9	240	15	170	2 MCL
atrazine	40	18	87	33	60	100	3 MCL
isoxaflutole	2.25	1.28	7	3.5 [5](6.2)[8]	3 [5]	147 [5](134)[8]	3.1 DWLOC [4]
202248	-	-	-	326 [8]	61 [1]	17 [8]	-
203328	-	-	-	-	977 [1]	-	-
metolachlor	78	19	39	530	90	200	100 HA

§ - Chemical properties are from USDA NRCS' Pesticide Screening Tool, except as noted. Application rates are from product labels registered with the Nebraska Department of Agriculture.
¶ - Rate is often dependent on a combination of soil types, the formulation of product, the number and method of application, and whether the product is used by itself or in combination with other herbicides.
† - Soil organic carbon sorption coefficient; measures the affinity of pesticides to sorb to organic carbon. The higher the value, the greater the tendency to attach to and move with soil.
‡ - MCL = Maximum Contaminant Level, the maximum permissible level of a contaminant in water delivered to users of a public water system. An enforceable standard;
DWLOC = Drinking Water Level of Comparison, the theoretical upper limit of "acceptable" exposure after considering food and residential exposures as sources. Not a regulatory standard for drinking water;
HA = Health Advisory level, an estimate of acceptable drinking water levels for a chemical substance based on health effects information. Not a legally enforceable Federal standard, but serves as technical guidance to assist Federal, state, and local officials.

References

[1] U.S. Environmental Protection Agency. (September 1998). *Pesticide Fact Sheet.* http://www.epa.gov/opprd001/factsheets/isoxaflu.htm (22 December, 2000)

[2] European Scientific Committee on Plants. (May, 1999) *Opinion of the Scientific Committee on Plants Regarding the Inclusion of Isoxaflutole in Annex 1 of Directive 91/414/EEC Concerning the Placing of Plant Protection Products on the Market. SCP/ISOXA/012-Final.* http://europa.eu.int/comm/food/fs/sc/scp/out40_en.pdf (18 December, 2000)

[3] U.S. Environmental Protection Agency. (September, 1998). *Conditional Registration of Isoxaflutole.* http://www.epa.gov/opp00001/chemicals/isoxaflu.htm (22 December, 2000)

[4] Written communication from Aventis to monitoring cooperators in Nebraska. October, 2000.

[5] USDA-NRCS National Water and Climate Center. (July 7, 2000). *Windows Pesticide Screening Tool (WIN-PST)*. Version 2.0050. http://www.wcc.nrcs.usda.gov/water/quality/frame/pestmgt.html

[6] USDA National Agricultural Statistics Service (NASS). (17 May, 2000 revised 11 November, 2000). *Agricultural Chemical Usage : 1999 Field Crops Summary*. http://usda.mannlib.cornell.edu/reports/nassr/other/pcu-bb/agch0500.pdf (3 January, 2001)

[7] U.S. Environmental Protection Agency. (Summer 2000). *Drinking Water Regulations and Health Advisories*. EPA-822-B-00-001. http://www.epa.gov/ost/drinking/standards/ (27 December, 2000)

[8] Taylor-Lovell, S., G. Sims, L. Wax, and J. Hassett. (2000). *Hydrolysis and soil adsorption of the labile herbicide isoxaflutole.* Environmental Science and Technology. 34:3186-3190.

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